Technical Bulletin 86 December 1932

University of Minnesota
Agricultural Experiment Station

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H. C. H. KERNKAMP[1]

INTRODUCTION

"Anemia of suckling pigs" is a disease of baby and young pigs that is marked by blood changes characteristic of a secondary anemia. This disease was first brought to the attention of veterinarians and swine growers by two English workers, McGowan and Crichton (17), in 1923. Since then it has been observed and described by workers in Denmark, Germany, Canada, and the United States. The disease is often responsible directly or indirectly for the loss of young swine by death or a loss in ability to grow and develop properly. The fact that this disease occurs more often in winter and early spring litters than in those farrowed at other seasons of the year, led to the general plan of procedure followed in this investigation.

The studies herein described deal with some of the physiologic and pathologic variations in the blood of baby and young pigs free from or affected by the so-called "anemia." The clinical manifestations and gross post-mortem findings are also discussed. The pigs studied ranged in age from birth to approximately three months. They were the progeny of pure-bred matings, cross-bred matings, and pigs of no special breeding. The environmental conditions, except in one particular, were the same for all the pigs. The exception in this case was that in some instances pigs were farrowed and reared to 80 days of age in pens, the floors of which were covered with loam to a depth of from 3 to 4 inches; others were farrowed and kept in pens having concrete floors. The blood of the pigs was studied at regular intervals throughout the experimental period. The studies included chiefly numerical counts of the red and white cell series, differential leucocyte counts, some of the morphological characteristics of the corpuscles and estimations of the hemoglobin content of the blood.

REVIEW OF LITERATURE

The review of the literature has for its object the collection of data of hematological interest as it relates to the blood of nursing (baby) and young pigs in particular.

[1] The writer wishes to express his appreciation to Eileen S. Davis and Hazel Hammersland for much of the technical assistance in connection with the study, and to Dr. C. R. Donham for advice and assistance with the biometrical treatment of the data.

That the reader may become familiar with the values or numbers characteristic of some of the components included in a "blood picture" of swine in general, the following brief summary is given. This summary is taken from a very excellent review by Scarborough (23) of all available recorded findings on the hematology of swine. The averages are based on the findings regardless of the age, weight, environmental conditions or geographic locations of the swine reported by the various workers. The average number of erythrocytes per cmm. of blood is reported as 6,740,000. This is based on the results of 215 counts that were made by 16 different workers. The average number of leucocytes found in 140 counts by 12 workers is 15,820 per cmm. The range, and this is given as normal, is from 8,000 to 20,000 per cmm. The average differential count with the approximate normal range (given in parentheses) is given as: lymphocytes 52.1% (40-60); polymorphonuclears 39.0% (30–50); large mononuclears and transitionals 3.3% (1–10); eosinophils 4.5% (1–10); basophils 1.2% (0–4). It is pointed out that physiologic variations of the leucocytes occur and that these are affected by age, sex, pregnancy, and a digestive leucocytosis. Tabulation of the hemoglobin values of the blood was more difficult because of the different methods of its estimation employed by the various investigators. However, according to the Sahli method (employed by a majority of the workers) the percentage of hemoglobin was usually between 80 and 90. Reference is made to work that tends to show that the percentage of hemoglobin is higher in older animals than in young animals and higher in males than in females. Nucleation of red blood cells, in the form of normoblasts, has been reported in swine and it is stated that these occurred in greater numbers in the blood of young pigs. The review contains fewer reports on such matters as the specific gravity, coagulation time, blood volume, resistance of red cells to saline solutions, and on the platelets found in the circulating blood.

Within the last few years, several workers have made more extensive studies on the blood of baby pigs, many of which include the findings observed at or near the time of birth. The hemoglobin in grams per 100 cc. of blood in pigs at the time of birth and that were farrowed indoors, varied somewhat according to the records of the several workers. Hart, Elvehjem, Steenbock, Bohstedt, and Fargo (14) in Wisconsin, record an average of 8.7 grams of hemoglobin per 100 cc. of blood; Craig (4), in Indiana, records 9.5 grams; Craft and Moe (5), in Oklahoma, 9.7 grams; Hamilton, Mitchell, and Carrol (13), in Illinois, 10.7 grams; and Doyle (7), in Indiana, 11.7 grams. Schofield (24), in Ontario, records an average of 67% hemoglobin according to the method of Dare. This figure when calculated on the basis of 100%

on the Dare hemoglobinometer equals 13.77 grams hemoglobin per 100 cc. of blood (manufacturer's standard), will be equivalent to 9.2 grams, an amount comparable to the results recorded by the aforementioned workers. Hamilton also gives the red cell counts on these pigs, which averaged 6,660,000 per cmm. The average hemoglobin per 100 cc. of blood in a litter of pigs at time of birth, but which had been farrowed outdoors and in pasture, is recorded by Craig as 12.7 grams. Craig also reports on a litter that was farrowed outdoors but in pens with concrete floors. The hemoglobin in this case averaged 7.6 grams. This litter, Craig says, was extremely anemic at birth. von Falck (9) in Germany, reports the hemoglobin at birth to be 15.6 grams, and Adsersen (1) in Denmark, 51% by the Sahli method. This, when calculated to conversion in terms of grams of hemoglobin per 100 cc. would approximate 8.0 grams.

For pigs one day old, whether farrowed and kept indoors in floored pens or farrowed outdoors and kept in floored pens, the hemoglobin content of the blood averaged 8.0 grams according to studies by Doyle, Mathews, and Whiting (8). The erythrocyte count on these pigs was 4,800,000 for the former and 5,000,000 for the latter group.

Palmer (21), in Minnesota, reported for a pig two days old that had been kept indoors, a hemoglobin value of 55% (Sahli); 2,864,000 red blood cells, and 8,000 white blood cells per cmm. For two-day-old pigs Adsersen found the average to be 50.5% (Sahli) of hemoglobin in the blood.

In Saskatchewan, Fulton (10) records the average hemoglobin for pigs three days old kept indoors and in pens with concrete floors to be 46.5% (the method of estimation not stated) and for pigs of the same age but farrowed outdoors and kept in floored pens, 43.7%. For pigs one to three days old, von Falck reports 10.5 grams of hemoglobin.

The hemoglobin on five-day-old pigs, according to von Falck, was 9.1 grams. Senftleben (25), in Germany, reports on pigs of this age 48.0% (Sahli) hemoglobin, 3,500,000 red cells, and 9,500 white ones. He also records 30.0% of the leucocytes were lymphocytes and 65.0% polymorphonuclears. Gütig (12), in Hungary, gives 5,794,000 red cells and 9,500 white ones as the average number per cmm. in six-day-old pigs.

For pigs one week old and kept indoors, Hart (14) records 5.0 grams of hemoglobin to be characteristic of the average; Craig, 7.2 grams per 100 cc; and Doyle, 8.2 grams. Schofield gives an average of 30% (Dare). The average for a group seven days of age and kept indoors but which had access to soil was 9.5 grams, according to Doyle. Another group kept under the same conditions except that they had access to green alfalfa instead of soil, averaged 6.6 grams of hemoglobin. Craig records a group of pigs seven days old kept outdoors and in pas-

ture as having an average of 8.9 grams hemoglobin per 100 cc. of blood; Hamilton reports 5.7 grams on a group kept under similar conditions and Schofield gives 47.0% (Dare) as the average for a group he studied. Craig reports 4.4 grams of hemoglobin in pigs seven days old kept outdoors in floored pens.

Fulton reports 38.0% hemoglobin (method of estimation not stated) and 3,112,000 erythrocytes as the average for pigs 13 days old kept indoors in floored pens. Pigs of the same age that were outdoors and on pasture had 64.3% hemoglobin and 4,999,000 erythrocytes.

Hart (14), Craig (4), and Doyle (7) found 4.0, 5.4, and 6.5 grams, respectively, as the average hemoglobin content in pigs 14 days old kept indoors and in floored pens. Schofield gives 21.0% (Dare) as the average for pigs 14 days old living under similar conditions. Doyle, on a group of pigs 14 days old, living indoors but having access to soil, finds the hemoglobin to be 8.2 grams. In another group living indoors but with access to green alfalfa, the hemoglobin was 5.6 grams. Fourteen-day-old pigs in outdoor floored pens had 5.0 grams of hemoglobin according to Craig. The average hemoglobin content of the blood in pigs of this age permitted the run of a pasture is given by Hart as 8.0 grams and by Craig, 11.3 grams. Adsersen gives 25.0% (Sahli) as the average hemoglobin for pigs from 7 to 14 days of age and von Falck, 10.4 grams for 15-day-old pigs.

At three weeks of age Hart finds 3.0 grams of hemoglobin per 100 cc., Hamilton 3.3 grams, Craig 4.8 grams, and Doyle 5.4 grams to be the averages for pigs kept indoors and in floored pens. Schofield records 20.0% (Dare). Doyle gives 9.6 grams for those kept indoors and with access to soil as against 4.7 grams for pigs with access to green alfalfa. For pigs of this age that were outdoors and on pasture, Hamilton records 7.7 grams; Craig, 12.4 grams; and Schofield, 55.0% (Dare).

Pigs that were 26 days old that had been farrowed and kept indoors at all times, showed an average of 4,500,000 red cells per cmm. and 5.3 grams hemoglobin according to the findings of Doyle. These findings are to be compared with those obtained on another series of pigs that had been permitted the run of a pasture at all times. The findings in this series was 5,400,000 red cells and 8.5 grams hemoglobin. In another series reported by Doyle on a group of pigs 28 days old the hemoglobin of those farrowed and kept indoors in floored pens averaged 5.1 grams; those kept indoors but with access to soil, 10.8 grams; and the ones kept indoors and having access to green alfalfa, 4.4 grams. Craig reports an average of 5.4 grams for pigs farrowed outdoors but kept in floored pens and 12.1 grams for those farrowed outside and kept in pasture. von Falck gives 12.7 grams hemoglobin and Gütig, 6,260,000 ery-

throcytes and 9,500 leucocytes per cmm. for pigs 28 days old. Craft records 11.5 grams hemoglobin per 100 cc. in pigs 30 days of age.

Hemoglobin determinations made by Craig on 35-day-old pigs which had been kept on floored pens and indoors from birth, showed an average of 5.0 grams per 100 cc. The same author reports 6.1 grams hemoglobin for those kept in floored pens but could be outdoors. A hemoglobin reading as low as 2.8 grams is given by Hamilton as representing the average on a group of pigs 39 days of age that had been kept indoors and in floored pens; for those living outdoors and on pasture, the average was 10.0 grams.

The hemoglobin values on pigs from 20 to 30 days old reported by Adsersen was 25.0% (Sahli) and 40.0% when they were 40 days old. Regner, in Austria, as quoted by Rudolph (22), reports 30.0% (Sahli) hemoglobin, 3,630,000 red blood cells and 11,000 white blood cells as characteristic blood findings in nursing pigs. This worker reports a differential leucocyte count wherein he finds 35.0% lymphocytes, 3.2% large mononuclears, and 62.7% polymorphonuclears. Burnett (2), quoting Storch, gives the erythrocyte count on pigs from 6 to 35 days old as 4,900,000 and the white cell count, 11,518. Senftleben records 71.0% (Sahli) hemoglobin, 6,500,000 red, and 21,500 white cells for pigs 42 days of age. The leucocyte differential given is 52.0% lymphocytes, 3.5% large mononuclears, 43.0% polymorphonuclears, and 0.6% eosinophils.

Passing now to what we consider young pigs, i.e., from 45 to 90 or 100 days of age, we find Schofield records the hemoglobin of the blood at 70.0% (Dare) for pigs 56 days old. These pigs had been indoors and in floored pens since birth. For pigs 60 days of age and living in pasture since 15 days old, Craft finds the hemoglobin value to be 12.7 grams. At 90 days this writer records 13.2 grams hemoglobin in 100 cc. of blood and 12.9 grams at 120 days. Giltner (11), in Alabama, found an average red cell count of 8,196,000 and a white cell count of 18,000 in a series of pigs that were 75 days old.

In this brief review we have attempted to emphasize certain blood changes that occurred during the babyhood and young-pighood periods in the course of the life of a pig. To make this more evident, a chronologic arrangement of some of the salient facts found in the literature and that bore the closest relation to this investigation was considered advisable. Reference was repeatedly made to the environment, as it plays an important part in some phases of the blood picture. The mention of the geographic location in connection with the introduction of the different workers served to show where these studies were undertaken. The number of animals included in some of these reports was small and therefore they do not represent a fair sample. However, the

accumulation of these findings will help toward the establishment of a norm for baby and young swine.

OBJECT, PLAN, AND PROCEDURE

Primarily, the object of this investigation was a study of the factors and conditions under which the anemia syndrome develops. Secondarily, the object was to collect hematological data on new-born pigs and those in the nursing and pighood stages of life. A third object was a study of ways and means of preventing and overcoming the development of the disease.

Clinical and field experience teaches that in this section of the country the disease is more prevalent in late winter and early spring. Climatic conditions in February and early March necessitate in most instances that the pigs be farrowed and kept indoors. The pens and runways in which pigs of many of these early litters are kept are usually constructed of concrete, plank, or other hard-surface flooring. It appears that this is a factor of importance in connection with the occurrence of this disease. Contrasting these conditions with those under which the disease is seldom seen is a point of much value in connection with an investigation designed to learn something more about the so-called anemia of suckling pigs. For example, this syndrome is seldom, if ever, seen in pigs that run in pasture at least within a few days after birth.

The plan followed in this investigation was to have the sows farrow the pigs indoors and to rear them indoors until they reached approximately three months of age; further, to examine the blood of all pigs at regular intervals throughout the experimental period. The care and handling of all the pigs were to be the same except that some of the sows and their progeny were to be kept in pens having concrete floors while others were to be kept in pens, the floors of which were covered with loam soil.

The pens were large, providing 180 square feet of floor space. They were all located in a one-story building well lighted by windows in the walls and roof. The building was warmed by artificial heat so that in winter the room temperature seldom went below 50° F. The concrete floors of some of the pens were covered with loam soil to a depth of approximately four inches. The soil is known to soil technologists as "Thurston loam" and is composed of clay, silt, and sand in about equal proportions. It was obtained from a dark, partly excavated basement beneath one of the buildings on University Farm. This particular soil had not been subjected to sunlight, rains, or frosts for more than twenty years. Straw sufficient to provide a comfortable nest, or

bed, was placed in both the pens with a cement floor and those with loam soil. Adequate feeding and watering troughs were placed in each pen. It was arranged that the sow should farrow in the pen and then she and her litter remain in it until the pigs were weaned. The sow was then removed but the pigs were to continue living in the same pen until they were discharged from the experiment.

The pigs used in the investigation were in some cases the progeny of pure-bred sows, others of grade sows, and still others of sows of no special breeding. The breeds represented were Chester White, Duroc Jersey, Poland China, and Hampshire and others of cross and recross breeding. In some cases the sows were pregnant when first received; others passed the entire gestation period on the premises. No previous history of some of the sows could be obtained and where known it was of no special handling. The care, management, or treatment given them while in our possession was uniform in all instances near the time for farrowing. Two or three days before parturition the sows were placed in one of the pens and remained in it until the pigs were weaned. During their period of rest and subsequent gestation they were permitted to run outdoors in dry-lot pens when climatic conditions were favorable. The ration supplied the sows consisted of ground corn 200 parts, ground oats 100 parts, protein mixture 60 parts, and three pounds of steamed bonemeal and one pound of salt per 100 pounds of feed. The protein mixture was composed of 40% meat-meal tankage 50 parts, linseed meal 25 parts, and alfalfa meal 25 parts. The weaned pigs received a similar ration except that no oats were included.

The examination included the making of total erythrocyte and leucocyte counts and the determination of the amount of hemoglobin. Differential leucocyte counts and a reticulocyte count were made on many of the pigs, and the morphological characteristics of the cells were noted in the smear preparations. All counts of red and white cells were made by using but the one diluting pipette. Toisson's fluid was used for making the dilution and a dilution of 1:200 was adopted. A hemocytometer with a Neubauer ruling was used for counting, and both red and white cells were counted in the same chamber. Wright's method of staining was used for making the differential count and for studying the morphological characteristics of the cells. Reticulation in the erythrocytes was determined by a method of vital staining, using brilliant-cresyl stain. The hemoglobin analyses were made according to a method devised by Newcomer (18). By this method the number of grams of hemoglobin in 100 cc. of blood is determined. The Klett hemoglobin disc, or glass plate, employed for the colorimetric step in this method was calibrated for swine blood. The disc employed was

equivalent to a 0.0351 per cent hemoglobin solution. The acid hematin solution stood at least three hours before it was read. The blood for making these determinations and for the other examinations was obtained by puncture of the auricular vein. The ear was washed, shaved, and swabbed with 70% alcohol before the vein was punctured. In most cases enough blood was obtained by this procedure for the purposes outlined. The hemorrhage was readily controlled by pledgets of cotton applied to the wound.

There is included in this study the examination of the blood of 153 baby and young pigs. The designation "baby pigs" includes the period from birth to weaning; "young pigs" from the time they are weaned until they are four or five months old. The age at weaning varied from 45 to 60 days. A total of 1,168 examinations was made, an average of 7.6 per pig. The intervals between examinations was approximately seven days. The reading, or determination, at birth is not made precisely at or immediately after delivery. On the other hand, the first bleeding to be reckoned as a reading at the time of birth was made within six hours. The interval was less than four hours in some cases. If the time between birth and the first bleeding was greater than six hours and not more than 42 hours, the reading was recorded as "second day."

THE FINDINGS

It seemed desirable to subject the data to a biometric analysis in order to determine the significance of difference between the mean, or average, values for each group. Two mean values are considered significantly different from one another only when the odds are at least 20 to 1 in favor of the difference being due to factors other than the errors of random sampling. These odds are generally accepted in biometric analyses of biological material and represent a conservative basis for deciding when significance of difference exists. When the odds are less than 20 to 1 the difference may have been due solely to the errors of random sampling. The odds are derived by determining the ratio between the difference of the means and the *standard error* of the difference of the means. This was done with the data on each group at every reported age. The standard error represents approximately 67 per cent of the range of the observations.

The Erythrocytes

The mean, or average, red cell count at birth on the pigs that were farrowed and kept in the pens with concrete floors was 6,190,000 per cmm. and the range was from 2,500,000 to 8,500,000. The mean for the group farrowed and kept in the pens with loam soil floors was

7,410,000, with a range of 5,000,000 to 10,000,000. These are important differences and will be discussed in the chapter entitled "Summary and Discussion."

The second blood examinations were made when the pigs were five days old. At this time the average count for the pigs on concrete was 3,659,000 red blood cells per cmm., and those on loam soil 4,330,000. These differences, like those observed at birth, are significant. The marked decline in the number of erythrocytes per unit volume of blood was very noticeable on this date. The proportionate decrease was about equal in both groups. This decrease appears to be physiologic and marks a time when certain postnatal erythropoietic adjustments were taking place.

The third examination period occurred when the pigs were 12 days old. Those on concrete had an average of 3,462,000 erythrocytes per cmm.; those on loam soil, 5,808,000. A range of from 2,000,000 to 5,500,000 red cells is recorded for the former group and 4,000,000 to 8,000,000 for the latter. These differences are quite significant and indicate that a difference of environment is a probable factor.

The mean red cell counts for the pigs on concrete when examined on the 19th, 26th, and 33rd days of age were 3,780,000, 3,918,000, and 4,484,000, respectively. In contrast to this the readings show averages of 6,040,000, 7,259,000, and 7,636,000 red cells for the pigs on the loam soil at the respective ages. These differences are very significant and point very clearly to differences of environment as contributary to the results.

When the pigs kept continuously on concrete were 40 days old they had an average erythrocyte count of 5,060,000. At 47 days it was 5,820,000; at 54 days, 6,083,000; at 65 days, 6,420,000; and at 80 days, 7,270,000. This shows a slight but steady increase and marks a period of spontaneous recovery from a state of oligocythemia. The average count for the pigs on loam during this period was approximately 7,000,000 at each bleeding. (Chart 1.)

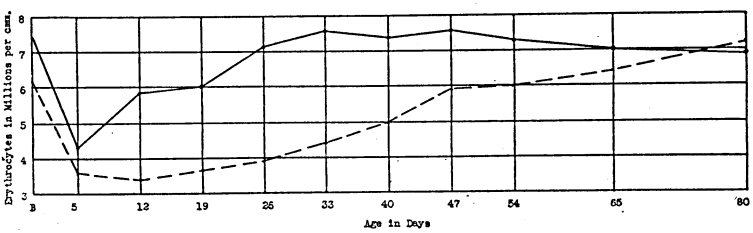

Chart 1. Average or Mean Values for Erythrocytes in Pigs on Loam Soil and Pigs on Concrete

Solid line = pigs on loam soil.
Broken line = pigs on concrete.

A critical analysis of the data with reference to sex differences in the number of red blood cells per cmm. definitely shows that no particular difference exists. This applies to both groups in the series being reported.

An examination of the red cells by "supravital" staining methods shows, in general, that an increase in the number of reticulated red cells occurs for the first two to three weeks of life. In many cases reticulation could not be demonstrated in the erythrocytes of pigs at this age. At the time of birth in the pigs on concrete, the percentage of reticulocytes, when present, was between 0.5 and 1.5%. In the group on loam soil reticulation was present to the extent of 10% in many cases. Examinations made when pigs were one week old showed an average of 4.5% reticulocytes per 500 to 1,000 erythrocytes. This figure was about the same in both the pigs on loam and those on concrete. At two weeks of age the percentage of reticulated reds was a little higher in the pigs on concrete, 6% as compared to 5.25%. Reticulation was less conspicuous in the group on loam soil as they increased in age, so when they reached 33 days of age the average percentage of reticulocytes was approximately 2%, and when 60 days old and older it dropped to approximately 1.25%. The range, however, is quite variable, as at almost any time from birth to 80 days it may vary between 0 and 20 per cent. The percentage of reticulocytes at 19, 26, and 33 days of age was approximately 11 in the pigs on concrete. From this point it decreased until the mean was 1.25% at 65 and 80 days. Wide variations occurred in this group as they did in those on loam.

The reticulation seen in the red cells represents according to Downey (6) a precipitation of the spongioplasm by the dye acting on the fresh cells. Reticulocytes represent a degree of immaturity of the erythrocytes, and when greater numbers are found in the circulating blood it is interpreted as signifying an active regeneration of the red cells or an increased marrow function. In appearance the reticulocyte is a red cell containing an interwoven, skein-like network, sometimes almost entirely filling the cell or occurring as a wreath just inside the periphery of the cell or as a small clumped mass in the center of the cell.

Stained smears (Wright's method) reveal a few normoblasts in the circulating blood at birth, and as a general rule a much greater number in the blood of pigs 12 days of age. It is not uncommon to find many normoblasts in cases showing an oligocythemia (4,000,000 erythrocytes per cmm. or less). When the pigs were two months old and the red count was 6,000,000 or more, the number of normoblasts was few. Jolly bodies, more often single but sometimes multiple, were often seen

when the number of erythrocytes was greatly reduced. Anisocytosis, poikilocytosis, microcytes, and hypochromasia were very noticeable in the anemic pigs. The degree of these abnormal morphological changes became less marked after the fifth and sixth weeks of life, and when they were nine and ten weeks old the degree was but slight. The evidences of regeneration were most characteristic in these cases. Regenerative changes, i.e., anisocytosis, Jolly bodies, and microcytes were more noticeable in the blood from the pigs on loam 26 to 33 days old than in those on concrete 47 and 54 days old. This should be expected because the regeneration of the blood and its return to a more normal state occurred much earlier in the "loam" group.

The Hemoglobin

The hemoglobin content of the blood is given in grams per 100 cc. of blood. The data, unless otherwise specified, represent the mean values, and the determinations were made at the time the numerical counts were taken.

An average of 9.5 grams of hemoglobin per 100 cc. of blood was obtained at birth for the pigs on the concrete floors. The range in this case was from 6.5 to 15 grams. For the pigs that were farrowed and kept on the loam soil, the average at birth was 11.7 grams and the range from 9.5 to 15.5. The hemoglobin values, like the values for the erythrocytes, were not the same for both groups. Further, the greater amount was in the blood of the pigs on the loam soil. This might be expected because of the greater number of red blood cells per unit volume in pigs on loam. Here again statistical analyses show that the two groups of pigs did not belong to the same population and that it was not the element of chance that made the selections as they were.

The hemoglobin averages obtained in connection with the blood examinations made when the pigs were five days old show a decrease in both groups; the pigs on concrete had an average of 5.7 grams hemoglobin per 100 cc. of blood and those on loam 8.1 grams. The proportionate decrease was about the same for both groups, e.g., 3.2 grams in the former and 3.6 in the latter. This is comparable to what occurred in the case of the red blood cells during the same period.

At the third examination period and when the pigs were 12 days of age, the mean hemoglobin value for the group on concrete was 4.5 grams. This is a further decrease from what it was one week earlier. On the other hand, the mean hemoglobin value for the group on loam at this time showed an increase over the fifth-day average. The mean now was 9.1 grams (Chart 2). There was an actual difference of 4.6 grams when the pigs were 12 days old, which is a very considerable difference.

The difference was still greater at the 19-day readings and even still greater at the 26-day reading. The average was 4.4 grams for the pigs on concrete when 19 days of age and 11.0 grams for those on loam. At 26 days the pigs on concrete averaged 4.3 grams and those on loam 12.6 grams. When the pigs that were farrowed and kept in the pens with concrete floors were 33 days old and again when 40 days old, the hemoglobin showed an average of 5.1 grams per 100 cc. of blood. This is a slight increase over what it was at 26 days. At the 47th day it had increased to approximately 6.5 grams. The reading on the 54th day was 6.9 grams; on the 65th day 7.1 grams, and on the 80th day 8.5 grams. The pigs on loam had an average of 13.5 grams of hemoglobin when 40 days of age. Beginning with the 47th day and at each subsequent examination period until the 80th day, the hemoglobin values decreased from 11.8 to 9.7 grams per 100 cc. of blood.

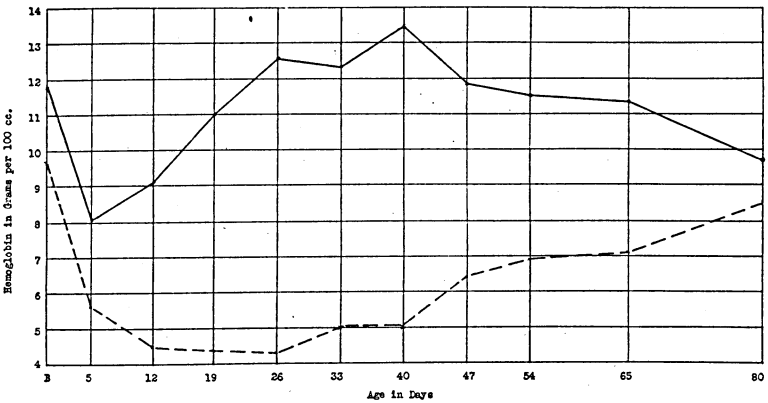

Chart 2. Average or Mean Values for Hemoglobin in Pigs on Loam Soil and Pigs on Concrete

Solid line = pigs on loam soil.
Broken line = pigs on concrete.

When the hemoglobin content of the blood reaches 3.5 grams per 100 cc. or less, a paleness and thinness of the blood becomes quite noticeable. The blood in such cases can best be described as "watery," and the color is a muddy yellow ochre.

With few exceptions the hemoglobin content of the blood of the males and females was so nearly alike that sex differences were of no consequence.

The Leucocytes

The average leucocyte count varied greatly at the several examination periods between the pigs on the concrete floors and those on the loam. At birth, the average count for those on concrete was 14,008

leucocytes per cmm. of blood and for those on loam was 13,785. An exceedingly wide range was obtained in the former group at this time. The lowest count was 5,500 and the highest, 33,000 per cmm. In fact, on three pigs the total leucocyte enumeration was greater than 31,000 per cmm. The examination in this case was made shortly after birth. The range in the pigs on loam at time of birth was from 9,500 to 20,500. The average for the groups when five days old was 12,045 for the pigs on concrete and 9,738 for those on loam. The range was 4,000 to 22,500 and 1,500 to 17,500, respectively. The means for the 12-, 19-, and 26-day readings were very similar for both groups. A count of approximately 10,500 per cmm. was characteristic for both groups at each of the three periods (Chart 3). The range, also, was similar for both groups throughout this time. Beginning when the pigs were 33 days of age and at each examination period for the rest of the investigation, the average number of leucocytes per cmm. of blood was slightly greater in those on loam. The difference, however, was about 4,000 white cells per cmm. The data show that the leucocytes increased in number, beginning when the pigs are about 26 days of age and continuing until at least three months. While the increase was more uniform and steady in the group on loam, nevertheless it was also evident in the pigs kept on concrete. The average for the pigs on concrete at 80 days of age was 17,578 per cmm. and for those on loam 22,812.

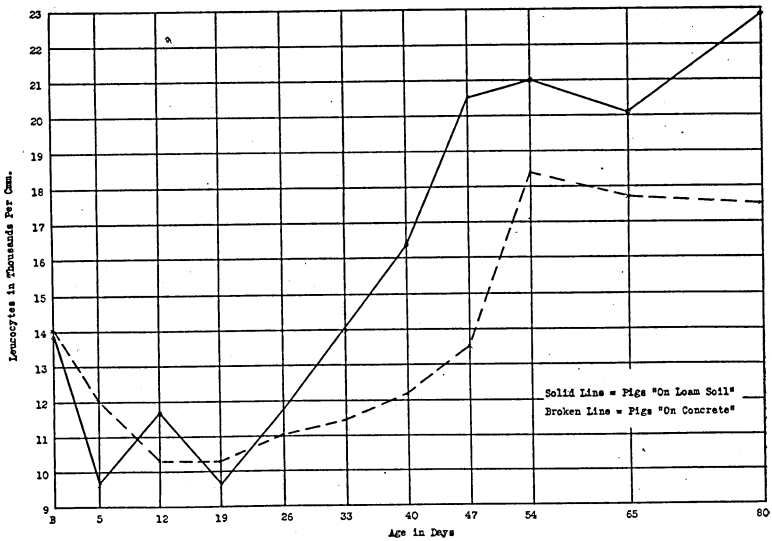

Chart 3. Average or Mean Values for Leucocytes in Pigs on Loam Soil and Pigs on Concrete

Solid line = pigs on loam soil.
Broken line = pigs on concrete.

Differential Count

A differential count was made to determine the relative numbers of the different varieties of white blood cells in both groups. The count included the lymphocytes, monocytes, polymorphonuclears, eosinophils, and basophils (Table 4). The findings do not show any marked differences between the two groups. There is, however, a slight difference in the percentage of monocytes and eosinophils in the two groups. The pigs on concrete had a slightly greater number of these cells than those on loam.

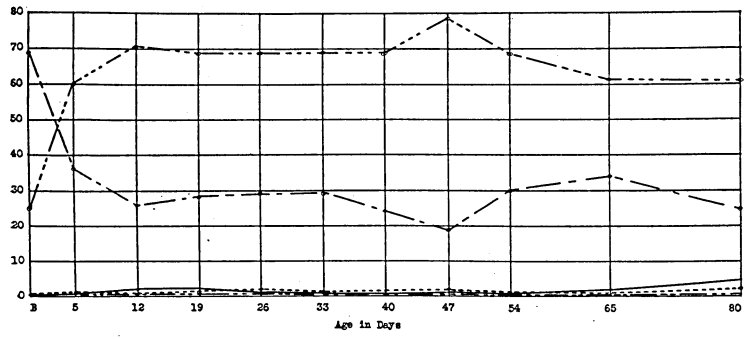

Chart 4. Differential Leucocyte Counts

Average or mean values for leucocytes in pigs on loam soil and pigs on concrete.

Dash and 3 dots = lymphocytes.
Dots = monocytes.
Dash and 2 dots = basophils.
Solid line = eosinophils.
Dash and 1 dot = polymorphonuclears.

The findings show very clearly that the proportion of lymphocytes to polymorphonuclears undergoes a very definite reversal between the time of birth and when the pig is five days of age (Chart 4). At birth the lymphocytes represented approximately 30% of the leucocytes counted, and the polymorphonuclears represented 69%. At five days of age, approximately 60% of the lecuocytes were lymphocytes and 39% were polymorphonuclears. The readings made when the pigs were 12 days old show a greater spread between these two varieties of leucocytes. At this age the lymphocytes constituted about 70% of the white cells and the polymorphonuclears, 28%. The greatest difference in the proportion of these varieties of cells occurred when the pigs were 47 days old. Here the difference was as great as 78% lymphocytes and 19% polymorphonuclears. The reversal phenomenon and proportionate differences between these two varieties of cells at the various ages were strikingly similar in both the pigs on concrete and those on loam.

An increase of eosinophils, particularly between the ages of 50 and 80 days, was noticed in both groups. The pigs on loam had 0.62% eosinophils at 54 days, 1.04% at 65 days, and 3.12% at 80 days of age.

The increase in eosinophils may be accounted for by the fact that some of the pigs harbored ascarids (*Ascaris suis*) and that in a few an eczematous condition occurred. Helminthic infections and certain irritations of the skin are said to produce a moderate eosinophilia.

The proportion of leucocytes that were basophils was practically the same for the pigs on concrete and those on loam. While the table (Table 4) shows that no basophils were observed in the smears made on the group on loam at birth and at the 26th- and 33rd-day examinations, cells of this species were found on these days but there were very few. The mean, therefore, was very small. Similar experience occurred in connection with the monocytes. The plus signs indicate that at least a few cells of this kind were found.

It will be noted that the percentage of monocytes recorded for the pigs on concrete is greater than for those on loam. The difference is greater by 10 times in some cases and less than one time in another. It is believed that the difference is of no significance.

Symptoms

Baby pigs and young pigs whose blood pictures show a marked decrease in hemoglobin (*oligochromemia*) and a decrease in erythrocytes (*oligocythemia*) along with marked evidences of degeneration (poikilocytosis and hypochromatophilia) and regeneration (anisocytosis, reticulation of red cells, nucleated reds, and Jolly bodies), present some very definite physical symptoms.

One of the earliest physical symptoms to be seen is a roughness or coarseness of the hair. The hair, instead of lying in a more or less horizontal plane, becomes more erect. It likewise becomes more lusterless and loses that sleekness and sheen so characteristic of young pigs in good health. A second symptom usually becomes noticeable about this time. This is the approaching dull and listless attitude so frequently exemplified as a prodromal indication of disease. With the blood picture showing still further oligochromemic and oligocythemic changes, the dull and listless attitude becomes much more marked. The head is more drooped, the upper eyelids droop, and the ears and tail hang more limply. When the pig is approximately two weeks of age, anasarcous symptoms are observed. The edema occurs in the subcutis of the neck, in the region of the withers and shoulder, and in the region of the thigh and leg. This is characterized at first by an appearance of plumpness and fatness and later a wrinkling of the skin in regions of the neck, shoulder, forearm, thigh, and leg. The skin sometimes becomes harsh, scaly-like, and dirty in appearance. Not infrequently a considerable amount of fluid collects beneath the skin and produces large edematous swellings. Hydrothorax, hydropericardium, and ascites can

be determined in the thorax, pericardial sac, and peritoneal cavities, respectively, by ausculation and percussion. These symptoms are more noticeable after three weeks of age. The visible mucous membranes are very definitely bleached and anemic in the more advanced cases. Respiratory symptoms characterized by thumpy and jerky movements of the flank are frequently seen, especially in cases with lesions of edema. By carefully auscultating the thorax, one can frequently determine that the heart is increased in size, as the heart sounds can be heard over a much greater area than in pigs not affected by this condition. For example, the sounds may be distinctly heard as far posteriorly as the 10th intercostal space and dorsally to a point representing the place of junction between the proximal and middle thirds of the rib. The death rate from this condition has been stated to be upward of 50 per cent in some herds. This figure is very much greater than the death rate from "anemia" experienced in connection with this investigation. The losses from "anemia" occurred only in the group that was on concrete and the mortality was only 9 per cent. As many as 81 per cent of the pigs in this group showed physical symptoms, whereas none of the pigs on loam showed physical symptoms that were considered suggestive of the disease.

The blood picture, a most valuable clinical adjunct in connection with this condition, has been discussed in detail above. The results of the blood examination must be weighed carefully and considered in the light of the stage of the disease at the time the examination is made. Of all the components relating to the blood picture, an estimation of the hemoglobin is first in importance. Hemoglobin values of 2.5 grams per 100 cc. of blood or its equivalent by any other method of estimation, approach the critical point between life and death of the patient.

Post-Mortem Findings

The bodies of many pigs that die from anemia give evidence that a fair to good state of nutrition existed before death. This is shown by the rotundity of the body and the absence of appearance signifying a state of undernourishment. The fact that the body often does give the appearance of a good state of nutrition is a point to be emphasized, as in the case of many diseases of three or more weeks' duration inanition and cachexia are evident. On the other hand, in many cases the bodies of pigs dying from this disease show signs of poor nutrition. The hair is dry, rough, and coarse, and the skin, especially in those showing inanition, is rough and scaly-like and often appears greasy. Frequently the skin is thrown into folds or wrinkles. This may be noticeable in the pigs showing evidence of either good or poor nutrition.

The folds or wrinkles occur about the neck, shoulders, and thighs particularly. The skin and subcutaneous tissues in the region of the pharynx and the ventral surfaces of the neck are often greatly thickened and swollen. The thickness and swellings suggest an enlargement of the thyroid gland, a so-called "goiter neck." An incision made into this and similar areas results in a transudation and the escape of a clear, yellow-tinted edematous fluid from the "water-logged" subcutaneous tissue. The more or less generalized anasarca that is sometimes found plays a part toward giving the body the appearance of one in a state of very good nutrition. A considerable amount of subcutaneous fat is often present, even in pigs showing some of the characteristics of inanition.

The thoracic and abdominal cavities often contain large quantities of watery fluid. From a 30-day-old pig weighing 16 pounds, 350 cc. of fluid was obtained from the abdominal cavity at autopsy. The pericardial sac frequently contains great amounts of fluid and occasionally one finds the sac distended with blood (hemopericardium). In some of the more protracted cases, clumps of fibrin may be found in the fluids. Adhesions often occur between the viscera and between the viscera and parietal walls of both the thoracic and abdominal cavities.

The heart is dilated and may increase from one-half to one or more times its normal size. The heart muscle is pale, soft, and flabby. Fine beadlike and glistening deposits of fibrin are frequently observed on the epicardium in acute cases. In the subacute cases the epicardium is often covered with a fibrinous exudate. The exudate sometimes reaches a thickness of from three to four millimeters. In cases with a hemopericardium, the exudates attached to the epicardium appear more like clumps or masses of granular-like aggregations of fibrinous material (so-called *"bread and butter"* exudate). The lungs often appear to be collapsed and pressed against the mediastinum. They are edematous in many cases. The liver is generally enlarged and may in some instances increase about twice its normal size. In color, it is more pale than normal and it is distinctly mottled in many cases. The mottling varies from very small light and dark areas to areas measuring a centimeter or more in diameter. Often a loosely adherent, fibrinous exudate covers the diaphragmatic surface of the liver. On section, the liver may appear slightly oily or fatty. The kidneys in some of the subacute cases are very pale and have the appearance of cloudy swelling. The spleen does not show gross lesions of any particular significance. The skeletal muscles, connective tissues, and mucosa of the gastro-intestinal tract appear pale and more or less "washed out."

The blood that flows from incised vessels is watery in consistency and has a muddy yellow-ochre tint.

SUMMARY AND DISCUSSION

The results of this investigation show that a disease with blood changes characteristic of a secondary anemia often occurs in baby and young pigs that are obliged to live under conditions unnatural for their proper development and growth. By unnatural, we refer to the manner of rearing baby pigs in ways that prohibit them from obtaining the elements that appear to be essential for the proper functioning of hemopoiesis. We should perhaps be more specific and limit it to erythropoiesis, as the myeloid series does not seem to be involved. It is shown in this series that the disease can be prevented by establishing at least some of the conditions that are more natural for the development and growth of baby and young pigs.

If progressive stages of a disease of the blood are to be studied, a knowledge of the blood of normal subjects is essential. While swine are swine and blood is blood, nevertheless age, sex, breed, and environment may be factors responsible for differences in the blood at different periods of life. In other words, is it sufficient and is it proper to make comparisons between the blood pictures of swine one year of age and those of pigs one week or one month of age living under different environmental conditions? That there are differences in the blood pictures of pigs of different ages, differences between those of pigs of the same age but living under different environment, and differences between those of pigs of the same age and living under the same environment is clearly demonstrated in this series. Because much of the literature on the hematology of swine lacks specific information on environment and age (environment in particular), the full value of the report is lost. This criticism applies more particularly to many of the reports on the hematological studies on new-born swine and pigs in the nursing and pig-hood stages of life.

A matter of interest that occurred early in the investigation is the difference in the number of erythrocytes and amounts of hemoglobin in the two groups at birth. The mean red-cell count for the pigs on concrete at this period was 6,190,000 and for those on loam 7,410,000; and the hemoglobin averaged 9.5 grams and 11.7 grams per 100 cc. of blood, respectively. Such differences between any two pigs whether from the same litter or separate litters, whether receiving the same treatment or different treatments, would not be significant, as they fall at birth within what we consider a normal range for red blood cells and hemoglobin. However, the case to be considered is not a matter of differences in individuals but differences in the means of two groups of individuals. This changes the viewpoint and the differences now become significant. In fact, when the data were submitted to biometrical

analysis it showed that the odds were far greater than 20 to 1 that the difference was not due to random sampling (Tables 1, 2, 3), and that the pigs did not belong to the same population. The difference, then, must have been related to the environment of the sows at or near the time of parturition, or to the environment of the new-born pigs between the time they were born and the time they were bled, or to both. The sows were not placed in the respective pens, concrete floor or loam floor, until two or three days before parturition was expected. Farrowings occurred in the group on loam in February, March, May, and June and in the group on concrete in March, April, July, August, October, and November. All sows were permitted to exercise in outdoor runways unless climatic conditions were unfavorable. These conditions offered to them the opportunity to ingest soil if they so desired. Thus, when the sow was placed in the "loam" pen it was not that she had been deprived of access to soil for any great length of time. The new-born pigs were not bled immediately but not more than six hours lapsed between the moment of their birth and the first bleeding. In many cases the time was much less than six hours. They always had an opportunity to nurse before being bled, which means, also, that they could creep or walk about the pen to some extent.

That the erythrocyte and hemoglobin values in the two groups of pigs were different at birth is definitely shown, but the evidence is only circumstantial when it comes to attributing this difference to environmental factors, e.g., soil versus no soil. However, we believe that the differences of environment, which in this study were between pigs that had access to soil and others that did not, were responsible for the non-anemia in the former and the secondary anemia syndrome of the latter.

The only report in the literature on the number of red blood cells per cmm. at birth was that of Hamilton (13), who gives a mean of 6,660,000 in pigs in a group kept in floored pens and indoors. This number is in close agreement with the findings in the series being reported in this paper. The lowest red cell count was obtained on a pig in the group on concrete when the count was 2,500,000. This may be explained by the fact that a hemorrhage from the umbilical cord occurred and thus a simple anemia from loss of blood was produced. The highest red cell count at birth was in a pig in the group on loam and a count of 10,000,000 is recorded. The particular significance of this can not be explained but it is stated by Downey (6) and Nicholson (19) that an erythrocythemia is not abnormal in human infants for the first day or two of life.

The average hemoglobin values on pigs at the time of birth and that were farrowed indoors and in floored pens, vary considerably according to the reports of several workers. For example, Hart (14) re-

ports an average of 8.7 grams per 100 cc.; Craig (4), 9.5 grams; Craft (5), 9.7 grams; Hamilton (13), 10.7 grams; and Doyle (7), 11.7 grams. Schofield (24) reports 67% hemoglobin by the Dare method (this is equivalent to 9.2 grams). The average hemoglobin in this series for pigs kept under similar conditions was 9.5 grams. Craig finds that the average for the pigs that were outdoors and on pasture was 12.7 grams as compared to 11.7 grams for those indoors but in pens with loam floors. Craig's findings were comparable to our own in that there was a significant difference between pigs that had access to soil at birth and those that did not.

No reports were found in the literature that dealt with the leucocytes of the new-born pig. In the series we are reporting, the average leucocyte count in the new-born pigs on concrete was 14,000 per cmm. and in those on loam, 13,700. Unlike the case of the erythrocytes and hemoglobin, the leucocytes at the time of birth in the two groups of pigs were not significantly different. This was verified statistically (Table 3). Thus it appears that the myelopoietic tissues were not influenced by the treatment to which the two groups were subjected. However, when individual pigs are examined we find a very wide range between the lowest and highest leucocyte counts in the pigs on concrete. One of the pigs in this group had as low as 5,500 white blood cells per cmm. and two pigs had 33,000. The range for the pigs on loam was 9,500 to 20,500. A satisfactory explanation for these marked variations is not fully understood, as a majority of the pigs showed a range from 9,000 to 16,000, which is a large range. A differential count at this period resulted in the following means for the several varieties of leucocytes: lymphocytes, 30.3%; monocytes, 0.25%; polymorphonuclear neutrophils, 68.9%; eosinophils, 0.36%; and basophils, 0.025%. No differences of marked importance were noted between the groups.

A second interesting post-natal period in the life of a pig insofar as the blood picture is concerned is the period between approximately the third and tenth days of age. During this period certain very striking blood changes occur. Examinations of the blood when the pigs were five days old showed in both groups a very decided decrease in the total number of red blood cells and in the amount of hemoglobin. The mean counts of red cells were approximately 3,000,000 fewer than at birth, and the hemoglobin about 4 grams less per 100 cc. of blood in both groups of pigs. In some cases the hemoglobin did not decrease, and in other cases the decrease was 52% less than at birth. Adsersen (1), von Falck (9), Hamilton (13), Hart (14), and Schofield (24) all report a decrease in hemoglobin during the first week or ten days after birth. This is characteristic of human beings except that the time interval is greater. Williamson (28), in a work that is regarded a standard on the

hemoglobin content of the blood of man, reports finding that the hemoglobin of an infant a few hours after birth measures about 23 grams per 100 cc. of blood and when from three to five months of age it was 13.6 grams. Nussbaum (20) reports the hemoglobin of infants at birth ranged from 110 to 140% (Sahli) and at 14 days of age it was only 65 to 75%.

The examinations made on the 12th day after birth revealed some very striking differences in some of the blood components in the two groups of pigs. In the case of the pigs on loam a very perceptible increase occurred in the number of red cells per cmm. and in the amount of hemoglobin. On the other hand, a still further decrease in these elements was observed in the pigs on concrete. The results obtained by Hart (14), Schofield (24), Fulton (10), and Doyle (7) also point to continued retrograde blood changes in the pigs kept under "inside" conditions and to recovery tendencies in those that had an opportunity to obtain soil.

The increase of hemoglobin and erythrocytes continued in the group on loam until they reached about 33 days of age, then showed, in general, a slight but steady decrease until the examinations were discontinued at approximately three months of age. With the pigs on concrete, it was noted that the red blood cells increased slowly but steadily, beginning at some time between the 12th and 19th days and continuing throughout the experimental period. The hemoglobin, on the other hand, did not increase to any extent until about the 40th day. From this age and until the examinations were discontinued, the rise in the hemoglobin content of the blood was quite evident.

In addition to numerical differences of erythrocytes between the pigs on concrete and those on loam, differences in morphology of many of these cells were more marked in the former and occurred over a longer period of time. In general, the signs of regeneration were noted at an earlier age in the pigs on loam. These signs include variations in the size of the cells, the occurrence of some nucleated red blood cells or red cells whose cytoplasm is more reddish blue, and other red cells in which one or more small rounded and azure stained bodies can be noted. If such blood is examined that has been prepared by vital staining methods, a reticulation of many of the red cells will be observed. Inversely, degeneration signs were more in evidence for a longer period in the group on concrete. The signs of degeneration are the presence of red blood cells with odd shapes or contours, e.g., club-shaped, tailed, or flat; and by a paleness of many of the red cells. The regenerative signs did not overshadow the degenerative ones in the pigs on concrete until they were approximately two months of age whereas in the pigs on loam the regenerative signs were much in advance at three weeks of age.

These statements are based on the results as a whole since as regards aspects of the blood picture, individual pigs of one group might be characteristic of pigs of the other group at almost any time.

That differences in the hemoglobin content of the blood, in numbers of erythrocytes, and in time and quantitative physiological and morphological phases of the red cell series very definitely occurred between the pigs that were farrowed, raised, and continuously kept in the pens with concrete floors and those farrowed, raised, and continuously kept in the pens with floors covered with soil, have been observed in these studies. The data supporting these facts show the differences more convincingly beginning with the observations made on the 12th day after birth. The differences were even more striking on the 19th, 26th, and 33rd days. Whether or not the differences observed at the time of birth and at five days of age are included to be significant differences, it takes but little understanding to appreciate that they were significantly different at the 12-day observation. The data show further that these differences were not the result of chance selection. Then, if the differences were not the result of chance selection they must have been the result of some interventions set up in the investigation. The principal and we believe the only intervention was the free and unlimited supply of soil (Thurston loam in this case) that was accessible to one group of pigs and not to the other. A definite knowledge of the specific soil constituent or constituents responsible for these differences was not determined.

It appears from the findings that the leucocytes were not particularly affected by the treatment for the first four weeks of life. Except for the significant difference (where the odds were 71 to 1 that there was a difference at the 5th-day examination), there was no appreciable variation in the leucocytes between the two groups until 33 days of age. Beginning at 33 days and throughout the period until after 65 days, the differences were significant. Whether the differences during this period can be attributed to the same source as in the case of red blood cells and hemoglobin can not be said. On the other hand, we have some reason to suspect that the higher leucocyte counts in the pigs on loam could have been influenced by ascarid infestation, as an examination of the soil in two of the lots showed ascarid eggs that were presumably passed with the feces from the sow. However, if we are to assume that erythropoiesis was benefited by the soil (using it in an inclusive sense) it is also reasonable to assume that the myelopoietic tissues were also benefited.

The range between the lowest and the highest white cell count was often very great even between litter mates at any examination period. Furthermore, the variation was often great in any single pig from one

bleeding to another. Counts as low as 4,000 per cmm. were not unusual and occasionally they ran as low as 2,500. Readings like these were not confined to one group any more than to another and the physical condition of the pig was no different from that of another whose leucocyte count was 10,000 or more. The importance of these low white counts has its fullest significance in connection with the studies on the white blood cells in hog cholera made by Lewis and Shope (16), Thorpe and Graham (27), Shu (26), Hewitt (15), and Cole (3). Their work points to a leucopenia as a frequent blood finding in hog cholera and it has been suggested that leucocyte counts of 8,000 or less might be considered as quite diagnostic of hog cholera. While this may be true with older swine, it certainly was not the case with the suckling and young pigs included in the studies we are reporting. The basis for this statement comes from the fact that throughout the entire investigation there was never a case of hog cholera in any of the pigs under 11 weeks of age. This makes no denial of the probability that hog cholera is often attended by a leucopenia but merely draws attention to the point that the number of leucocytes per cmm. in young pigs may be lower than the average for older pigs under normal conditions. It appears from these studies that the normal range of leucocytes in baby pigs should be placed at from 9,000 to 16,000 at birth; 10,000 to 18,000 at six weeks of age; and 10,000 to 20,000 at 12 weeks of age. For pigs two days of age Palmer (21) records 8,000 per cmm. Senftleben (25) and Gütig (12) report 9,500 for pigs five and six days old, and Storch, quoted by Burnett (2), gives an average of 11,500 for pigs from 6 to 35 days of age. Giltner (11), Palmer (21), and Senftleben (25) record from 14,000 to 18,000 leucocytes for pigs between two and six months of age.

CONCLUSIONS

1. By establishing some of the conditions pertinent to the occurrence under natural conditions of a disease of suckling pigs in which a marked secondary anemia develops, the disease has been experimentally produced. The conditions provided aimed to exclude the baby pigs from all access to soil for at least five or six weeks, beginning from the moment of birth.

2. By establishing other conditions, at least some of which exist where no evidence of the disease is observed, the disease has been prevented and the secondary anemia picture minimized. The conditions provided in this case differ only in that these pigs had access to soil (loam) at all times from the moment of their birth until the investigation was terminated—when the pigs were approximately three months of age.

3. "Blood pictures" on all pigs were studied at regular intervals throughout the period, the intervals being of about seven days duration. Over 1,100 examinations were made on the blood of pigs included in this report. While no attempt is being made to define a specific normal mean or normal range for baby and young pigs as a whole, we do propose to give certain values which will approximate the norm. Similar studies on a greater number of pigs are necessary, before a more definite norm can be established.. The following ranges are proposed:

Birth—5,500,000 to 7,000,000 erythrocytes; 9,000 to 16,000 leucocytes per cmm. and 9 to 13 grams of hemoglobin per 100 cc. of blood.

One week—3,000,000 to 4,500,000 erythrocytes; 9,000 to 16,000 leucocytes; 6 to 9 grams hemoglobin.

Two weeks—where pigs have access to soil or its equivalent from birth: 5,000,000 to 6,500,000 erythrocytes; 9,000 to 16,000 leucocytes; 7 to 10 grams hemoglobin.

Two weeks—where pigs do not have access to soil or its equivalent from birth: 2,500,000 to 4,000,000 erythrocytes; 9,000 to 12,000 leucocytes; 3.5 to 6 grams hemoglobin.

Three to six weeks—access to soil or its equivalent: 5,500,000 to 7,000,000 erythrocytes; 9,000 to 16,000 leucocytes; 9 to 12 grams hemoglobin.

Three to six weeks—no access to soil or its equivalent: 2,500,000 to 4,000,000 erythrocytes; 8,500 to 11,000 leucocytes; 3.5 to 6 grams hemoglobin.

Seven to twelve weeks—access to soil or its equivalent: 6,000,000 to 7,000,000 erythrocytes; 14,000 to 20,000 leucocytes; 9 to 12 grams hemoglobin.

Seven to nine weeks—no access to soil or its equivalent: 5,000,000 to 6,000,000 erythrocytes; 11,000 to 18,000 leucocytes; 5.5 to 8 grams hemoglobin.

Ten to twelve weeks—no access to soil or its equivalent: 6,000,000 to 7,000,000 erythrocytes; 12,000 to 20,000 leucocytes; 7 to 10.5 grams hemoglobin.

4. The results of this study have shown very definitely that when reporting the blood picture of baby and young pigs it is imperative to make clear the conditions or environment under which they are living and specify the age, if it is known.

5. A decrease in erythrocytes, leucocytes, and hemoglobin occurs in pigs during the first week or ten days of life. The decrease is most marked in hemoglobin, less marked in the erythrocytes, and least marked in the leucocytes. The decrease is followed by a corresponding increase in pigs living in an environment more natural to their living. This decrease in red blood cells and hemoglobin appears to be physiological.

6. At birth the polymorphonuclear leucocytes were found in far greater numbers than were the lymphocytes. Twelve days later a complete reversal between these two types of leucocytes had occurred. The lymphocytes at this time represented approximately 69% of the leucocytes and the polymorphonuclears 28%. This relationship was maintained more or less throughout the rest of the experimental period.

7. It appears from the data that sex differences in baby and young pigs played no part in the numbers of erythrocytes and leucocytes or in the amounts of hemoglobin of the blood.

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Table 1

Data on Significance of Difference of Mean Erythrocyte Counts of Pigs on Loam and Pigs on Concrete

Age, days	No. of pigs		Mean		Standard deviation		Ratio	Odds
	On loam	On concrete	On loam	On concrete	On loam	On concrete		
Birth	28	58	7,410,714	6,129,310	1,284,186	1,194,138	4.4349	∞ to 1
5	21	44	4,333,333	3,659,090	397,896	653,908	5.1327	∞ to 1
12	34	40	5,808,823	3,462,500	1,279,292	949,409	8.8261	∞ to 1
19	25	42	6,040,000	3,738,095	1,040,032	1,269,906	8.0552	∞ to 1
26	52	61	7,259,615	3,918,032	888,328	1,232,141	16.6946	∞ to 1
33	22	33	7,636,363	4,484,848	1,025,650	1,360,637	9.7763	∞ to 1
40	24	33	7,458,333	5,060,606	1,062,276	1,418,392	7.2966	∞ to 1
47	52	39	7,673,076	5,820,512	733,548	1,397,780	7.5352	∞ to 1
54	21	24	7,380,952	6,083,333	1,584,259	3,844,847	1.5131	15.4 to 1
65	33	25	7,075,757	6,420,000	638,867	1,630,951	1.9028	34.5 to 1
80	16	57	6,906,250	7,271,929	554,439	1,353,141	1.6139	18.9 to 1

Table 2

Data on Significance of Difference of Mean Hemoglobin in Determinations of Pigs on Loam and Pigs on Concrete

Age, days	No. of pigs		Mean		Standard deviation		Ratio	Odds
	On loam	On concrete	On loam	On concrete	On loam	On concrete		
Birth	28	58	11,785,700	9,586,200	1,272,806	2,000,335	6.1756	∞ to 1
5	21	44	8,119,000	5,750,000	2,190,530	1,378,824	4.5448	∞ to 1
12	34	40	9,117,600	4,525,000	2,449,072	1,250,262	9.8934	∞ to 1
19	25	42	11,060,000	4,428,571	2,301,812	1,475,705	12.9117	∞ to 1
26	52	61	12,634,615	4,319,672	1,927,904	1,870,898	23.1635	∞ to 1
33	22	33	12,318,200	5,045,500	1,190,436	1,465,944	20.2069	∞ to 1
40	24	33	13,541,766	5,015,152	1,322,714	1,787,477	20.6972	∞ to 1
47	52	39	11,836,500	6,461,500	1,504,295	2,168,496	13.2689	∞ to 1
54	21	24	11,547,619	6,916,700	1,448,311	2,182,662	8.4928	∞ to 1
65	33	25	11,393,900	7,160,000	2,037,986	2,149,226	7.5966	∞ to 1
80	16	27	9,750,000	8,578,947	826,636	1,548,329	3.2293	∞ to 1

Table 3

Data on Significance of Difference of Mean Leucocyte Counts of Pigs on Loam and Pigs on Concrete

Age, days	No. of pigs		Mean		Standard deviation		Ratio	Odds
	On loam	On concrete	On loam	On concrete	On loam	On concrete		
Birth	28	58	13,785	14,008	4,972,942	6,778,764	0.1722	2.3 to 1
5	21	44	9,738	12,045	3,419,133	4,928,344	2.1913	71.4 to 1
12	34	40	11,691	10,362	4,091,777	3,864,298	1.4279	12.9 to 1
19	25	42	9,680	10,321	2,680,486	5,334,918	0.6529	3.8 to 1
26	52	61	11,807	11,024	3,914,720	3,719,728	1.0844	7.2 to 1
33	22	33	14,045	11,424	3,750,724	3,347,390	2.6492	200.0 to 1
40	24	33	16,395	12,272	3,526,235	4,376,947	3.9336	∞ to 1
47	52	39	20,461	13,589	6,105,183	5,208,382	5.7822	∞ to 1
54	21	24	21,119	18,416	3,282,169	5,345,998	2.0703	52.7 to 1
65	33	25	20,893	17,740	6,565,482	6,432,535	1.8328	30.3 to 1
80	16	57	22,812	17,578	5,192.544	2,953,990	1.2695	9.7 to 1

Table 4

Differential Leucocyte Counts of Pigs on Loam and Pigs on Concrete

	Age in days										
	Birth	5	12	19	26	33	40	47	54	65	80
Pigs on loam											
Lymphocytes	25.30	61.62	71.95	66.12	66.60	67.26	71.32	79.22	64.37	62.80	63.10
Monocytes	0.12	0.31	*	0.31	0.19	*	0.21	0.36	*	*	0.92
Polymorphonuclears	74.00	36.31	27.43	29.81	31.60	31.51	26.64	19.55	34.87	35.62	29.00
Eosinophils	0.62	0.56	0.52	1.39	0.42	0.57	0.70	0.68	0.62	1.04	3.12
Basophils	*	0.18	0.08	0.16	*	*	0.08	0.11	0.12	0.25	0.56
Pigs on concrete											
Lymphocytes	35.40	57.70	70.80	70.00	68.30	69.20	65.20	77.10	70.60	62.10	59.00
Monocytes	0.39	0.40	0.66	1.36	2.00	1.15	1.25	1.68	1.50	0.87	1.40
Polymorphonuclears	63.90	39.00	25.00	26.30	27.60	27.90	21.60	19.20	25.80	33.80	31.00
Eosinophils	0.10	1.00	1.87	1.95	1.33	1.25	1.50	1.25	1.50	2.10	6.60
Basophils	0.05	1.04	0.89	0.10	0.16	0.46	0.04	0.08	0.05	0.66	1.20

* A few cells of this kind were found.